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SOVEREIGN POTENTIALITY CONTROL AND DOMINANCE BETWEEN UNATTACHED DC MICROGRIDS

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Abstract

Owning to the intermittent nature of renewable energy, micro grids are popular in remote areas in qualifiable and quantifiable manner. Reliability of automatic DC micro grids (ADCMG) depends on battery capacity and size due to stochastic behavior of reusable. The overcharging and discharging of battery force the micro grid into insecure zone. Increasing storage capacity is not a thrifty solution because of additional maintenance and capital cost. The power management strategy for an autonomous DC micro grid based on a photovoltaic source, storage, battery. The main contribution of this paper centered on a power management strategy solving the above issues integrally, and analysis of micro grid. Furthermore, the study provided a comparison between the micro grids and controlling methods. Thus interconnecting neighbor micro grids increases virtual storing and discharging capacity when excess power and deficit scenario arises respectively in any of the DCMG.

Introduction

The smart grid is a next generation power system, in which the micro grid gathers the loads, storages and distributed energy resources operating as a single controllable electrical power systems. The micro grids power generation is mainly for self-consumption to decrease influence on the utility grid. With wide adoption of renewable DC power sources, the rapid progress of power electronics technology, and the gradual increase of DC loads in commercial, industrial, and residential applications, the DC micro grid largely attracts public attention due to its merits over the AC micro grid. The different control modes based on bus voltage deviation for regulating the DC micro grid under variable generation and storage. Well defined control loops are employed under each mode for enhancing the system working which requires frequent switching between control loops that causes switching transients and also increases burden on control processor. The deviation of bus voltage is more than 10% of nominal value in islanded mode which that affects the sensitive loads connected.

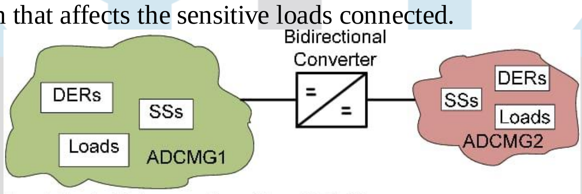


Fig. 1. Typical interconnection of two ADCMGs.

Various sources can shift their operating modes by extracting the information from different frequency signals. Besides, it consumes additional current from battery for dispatching the various signals. A power control and management strategy (PCMS) is developed based on DCBSM for individual ADCMGs and as well as between ADCMGs without any dedicated communication infrastructure.

System Structure

System contemplated is shown in fig 2 which consists of two ADCMGs broadly apart from each other with considerable line resistance between them. Each ADCMG consists of one photovoltaic (PV) source and battery as equivalent to group of sources from renewable sources and storage devices family respectively in order to simplify the analysis for proposed PCMS between the ADCMGs.

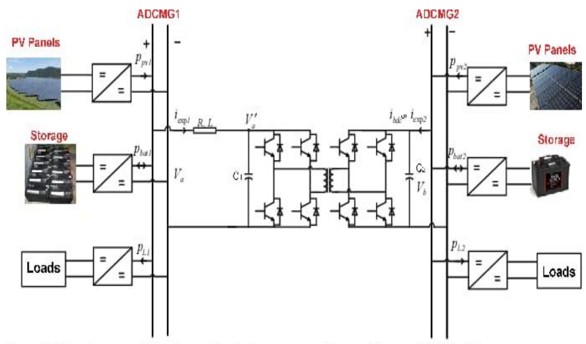


Fig. 2. System architecture for interconnection of two ADCMGs.

Most of DC loads are of constant power loads (CPL) which are integrated through DC-DC converter. Hence, CPLs can able to maintain fixed power irrespective of variations in DC bus when its voltage oscillations lie within sustainable range. PV source is interfaced to DC bus through boost converter and buck-boost DC-DC converter is utilized for connecting the battery storage. Interconnection of two ADCMGs is realized by considering DABC as interfacing unit which provides galvanic isolation and high power feeding capability in both directions along with large conversion ratios through high frequency transformer. As DABC is located nearby low voltage DC grid (i.e ADCMG2) to avoid losses, its bus voltage is directly available to DABC. Maximum capacity of PV source is higher than the rated battery charging power and load power to serve the loads most of the time through PV power. Nominal bus voltage deviations are within the tolerance band of loads.

Power Control and Management Strategy (PCMS)

Source and storage units of ADCMGs are operated based on bus voltage levels in the grid by making bus voltage as information carrier between the units. Operation of each ADCMG is divided into 5 zones. Each zone has particular voltage threshold to get activated.

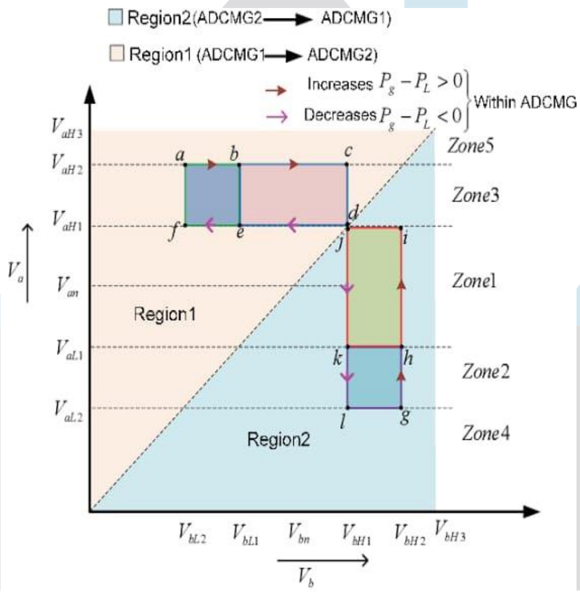


Fig. 3. Proposed PCMS between two ADCMGs.

Loads are managed depending on the state of charge (SOC) of battery and power condition of ADCMG which is expressed in terms of bus voltage deviation. Instantaneous SOC can be estimated by using coulomb counting method.

Zone-1 (Balanced power mode)

Power generated by PV source (PV1p) is more or less equal to demand (L1p) in the ADCMG1 which keeps battery in idle state. Minor variations of load and source will not trigger the storage unit in this mode because predefined voltage limits are able to sustain these fluctuations. There are no fixed source to regulate the bus voltage in this zone, which in turn permit its voltage to vary between the limits VaH1 and VbH1 that are treated as frontier of this mode for ADCMG1.

$$p_{PV1} \cong p_{L1}; \quad p_{bat1} = 0; \quad V_{aL1} < V_a < V_{aH1}$$

Zone -2 (Battery discharging mode)

Once Va fall below threshold value (VaL1) then storage steps into discharging mode to meet the demand. Battery screws the bus voltage at same threshold (VaL1)by keeping it in bus regulating mode.

$$p_{PV1} + p_{bat1} = p_{L1}; \qquad V_a = V_{aL1}$$

Zone-3 (Battery charging mode)

If the PV source is producing excess power than required, then this mode comes into picture. Battery is allowed to charge until its cutoff limit is met. ADCMG1 cannot feed the power to ADCMG2, but absorb the power from it when Vb is at VbH2 and battery1 in ADCMG1 is not fully charged or maximum charging rate is not met.

$$p_{PV1} > p_{L1}; \quad p_{bat1} = -(p_{PV1} - p_{L1}); \quad V_a = V_{aH1}$$

Zone-4 (Power deficit mode)

When load rises beyond discharging rate of battery. Battery runs at maximum discharging current limit. There are two sub cases exit in this zone, in which first case deals with power import from ADCMG2 where in second case it tells about ADCMG2 of no power import.

Case: 1

Status of ADCMG2 is checked against surplus power mode by observing its bus voltage (Vb) & status of ADCMG1 is known by its voltage (Va). Transmitted power can push the ADCMG1 to operate at different operating points in dissimilar zones depending on power imported in region2

$$V_a = \begin{cases} V_{aL1} & : if\ p_{PV1} + p_{bat1} + p_{imp1} = p_{L1} \\ V_{aL1} < V_a < V_{aH1} & : if\ p_{PV1} + p_{imp1} \cong p_{L1} \\ V_{aH1} & : if\ p_{PV1} + p_{imp1} > p_{L1}, p_{bat1} = -(p_{PV1} + p_{imp1} - p_{L1}) \end{cases}$$

Case: 2

In this case arises when ADCMG2 is not feeding either enough power or zero power to ADCMG1. Hence, load shedding is done as per the priority order in ADCMG1. Load sheds either based on decrement of SOC1 below cut off limit or falling of voltage Va below VaL2.

$$p_{PV1} + p_{bat1} + p_{imp1} < p_{L1}$$

$$p_{PV1} + p_{bat1} < p_{L1}; p_{imp1} = 0$$

Zone-5 (Excess power mode)

This zone is further split into two cases.

Case: 1

Either rise in generation or fall in load beyond the charging rate of battery will enforce the ADCMG into this operating zone. If the surplus power is not utilized within the grid then bus voltage started rising. If the ADCMG2 is in a state other than excess power case, then power is transferred from ADCMG1 to ADCMG2.

Case: 2

PV source will shift its operating mode from MPP to bus voltage regulation mode. On the detection of rise in bus voltage (Va) above VaH2, PV source will shift its operating mode from MPP to bus voltage regulation mode and clamps its bus voltage at VaH3.

$$V_a = \begin{cases} V_{aH2} & : if\ p_{\exp1} > 0 \\ V_{aH3} & : if\ p_{\exp1} = 0\ \&\ V_{PV1ref} = V_{aH3} \end{cases}$$

Control Loops

Converter control plays vital role in switching the source converters between different modes based on predefined thresholds for triggering. Unless the defined threshold voltage is reached by the DC grid, particular mode will not be active. Control of battery1 and PV source 1 inside the ADCMG1 is elaborated and the similar control structure utilized in ADCMG2 for battery2 and PV source2. There are 3 control loops in each ADCMG.

PV Control Loop

PV source always remain at MPP except in zone 5. It can be operated in two modes like MPP (maximum power point) mode and voltage regulation mode. It consists of two loops that are inner loop and outer loop. Here the outer loop is mainly tracking MPP voltage through perturb and observe (P&O) method and provides voltage reference as input to inner loop. Inner loop works at faster speed for tracking the given reference through PI controller and produce the duty cycle as its output. The voltage regulation has only one loop and comes into picture when case2 of zone-5 occurs (i.e ADCMG2 not able to absorb power available from ADCMG1).

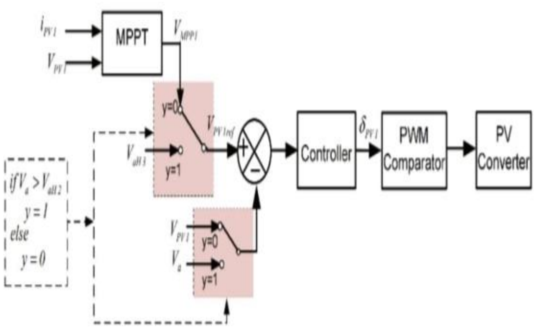


Fig. 4. Control loop of PV source in ADCMG1

Both the modes use the PWM comparator to generate the required pulses for switches inside the converter. Switching between two modes is done selectively by observing the bus voltage. If the Va increase above the upper threshold value, then PV enters into the bus regulation mode, otherwise PV keeps running in MPP mode.

Battery Control Loop

Battery is operated in two modes that are charging and discharging mode. Each mode employs two loops (inner & outer loop) in which inner loop is common for both the modes. Outer voltage loop mainly tracks bus voltage reference and produces the current reference as output, and that is fed to inner loop for tracking the reference effectively. In discharging mode the top outer loop gives the positive reference current (battery current) by regulating bus voltage (Va) at VaL1 as load dominates. Bottom outer loop is inactive. The cutoff limit of 1 SOC=20%. In charging mode the bottom outer loop and produces negative current reference to inner loop. Battery reference current is checked against charging current limit and full charge (i.e. 1SOC=90%) equivalent voltage to avoid high charging rate and over charging.

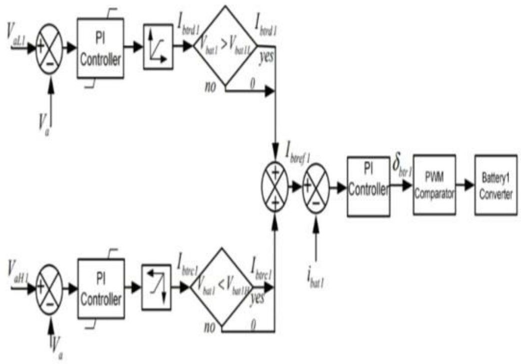


Fig. 5. Control loop of battery in ADCMG1

Power Control between ADCMGs

DABC (Dual Active Bridge Converter) is employed as bidirectional DC-DC converter (BDC) for transferring the power between ADCMGs. It works on conventional phase shift method. It consists of two loops which are outer voltage loop & inner current loop. BDC comes to active state when one of two ADCMGs possesses the surplus power and other grid is able to absorb.

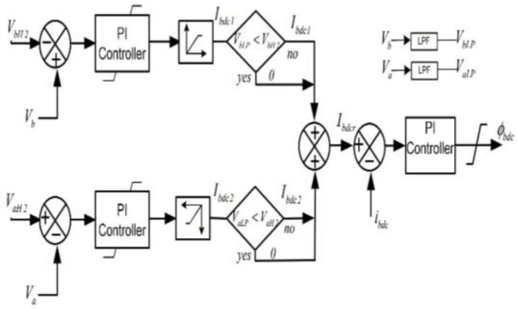


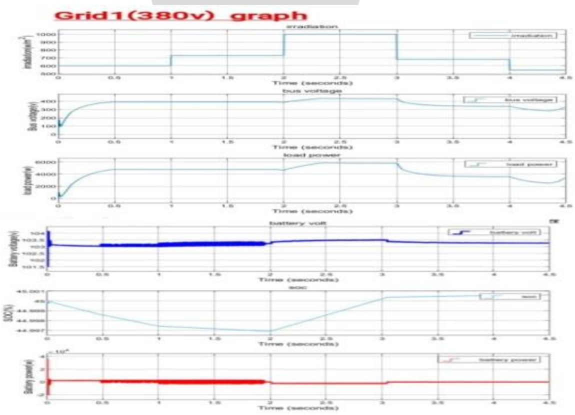
Fig. 6. Control of BDC between two ADCMGs

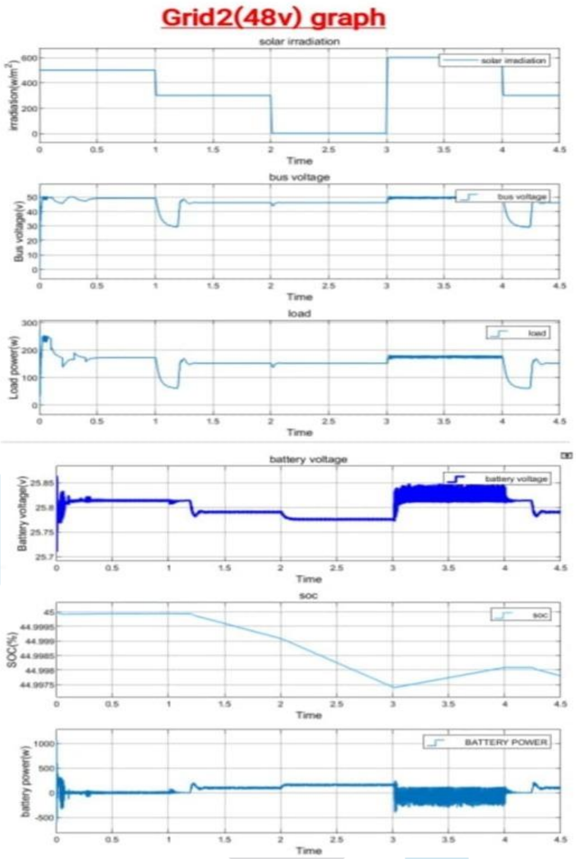
Simulation Results

Simulation of the system is carried out on real time digital simulator (RTDS) platform to validate the developed PCMS. Proposed PCMS is explored under various operating scenarios of ADCMGs including extreme conditions of battery and grid like overcharging and discharging, over load and under load scenarios of ADCMG.

Individual DC Micro grids

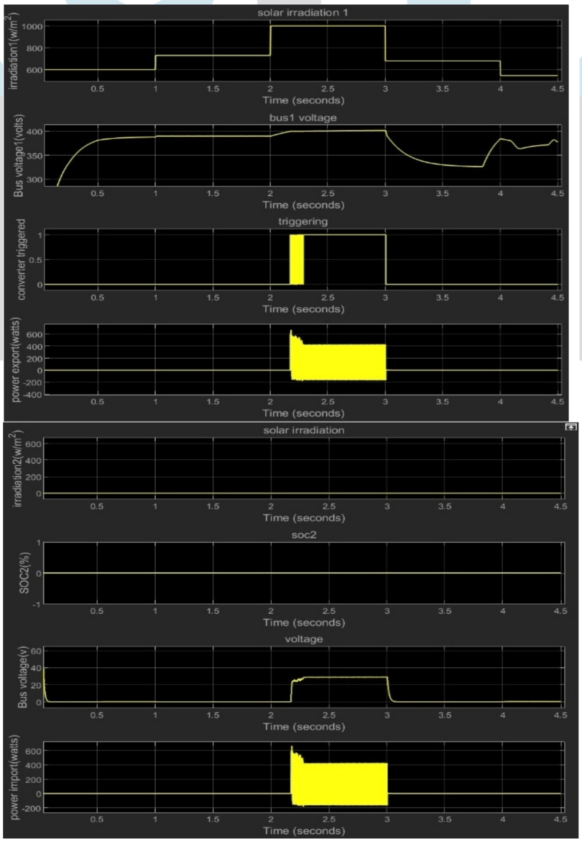
Many operating regions of ADCMG1 in battery terminal voltage is kept just above the lower cutoff limit to compile all zones including extreme conditions within the single window.





Inter DC grid Power Flow

Simulation of inter DC grid power flow using developed PCMS. Though power is transferred from ADCMG1 to ADCMG2, but ADCMG2 remains to be in zone2 since total available power within ADCMG2 including the power imported from ADCMG1 is less than the demand



Conclusion

A PCMS is developed based on bus signaling technique for inter DC grid power flow in case of ADCMGs to increase the system reliability and efficient utilization of resources. No communication line is required. It can be used in isolated locations where utility connection is not available or feasible. Application potential of system suits low and medium voltage customers like domestic consumers, data centers, telecommunication systems, etc. in isolated locations where utility connection is not present or feasible.

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